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Mt. Carmel Airport Cores Regarding Epoxy Striping

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CORE AND EPOXY STRIPING ANALYSIS

BACKGROUND

In September 2002, epoxy striping was applied to the existing hot mix asphalt (HMA) surface course on the runways at the Mt. Carmel airport in Wabash County. In the spring of 2003, the epoxy striping began peeling from the HMA surface. This deterioration has continued. All general areas on the runway have some separation of the epoxy striping. The deterioration of the epoxy striping is considerable in some areas, especially on runway #31.

On May 26, 2005 a meeting was held at the Bureau of Materials and Physical Research to discuss options for coring the runway pavement and for testing the HMA surface to determine if the HMA was responsible for the epoxy striping failure or if the HMA was performing within a "normal" range, considering that it had been in service for several years.

On June 02, 2005 a total of forty, four-inch diameter cores were taken from the runway. Thirty cores were taken from three locations (10 each location) on Runway #31 and ten cores were taken from one location on runway #4. The three locations on runway #31 were:

1. No epoxy was ever applied and the pavement is in good condition (**G**$_{ood}$**N**$_{oEpoxy}$).
2. Epoxy has been applied and is still present (at least in most of the area) although the epoxy coating generally is deteriorating. The pavement was generally in reasonable condition (**B**$_{adWith}$**E**$_{poxy}$).
3. Epoxy has been applied but has deteriorated and is no longer present. The Hot Mix Asphalt (HMA) pavement was still present but was deteriorated with at least some of the aggregates at the aggregate/HMA interface missing (**B**$_{ad}$**N**$_{oEpoxy}$).

On the end of runway #4:

4. No epoxy was ever applied on the HMA in this immediate area where the cores were taken ($_{Runway}$**4N**$_{o}$**E**$_{poxy}$), although epoxy had been applied nearby.

TESTS

- G_{mb}: The bulk specific gravity of each core was determined according to IL-modified AASHTO T 166.
- G_{mm}: The maximum specific gravity of the HMA was determined according to IL-modified AASHTO T 209 from the six tensile strength cores on runway #31 that had never had epoxy applied and from the six tensile strength cores from runway #4.
- Air Voids: The percent air voids were calculated using:

  $$\{100 \times [1-(G_{mb}/G_{mm})]\}$$

- Tensile Strength: The tensile strength was determined on six of the cores from each of the four groups according to IL-modified AASHTO T-283. In each group, three cores were unconditioned and three cores were conditioned in the 140°F water bath.
- Tensile Strength Ratio (TSR): The TSR was calculated by dividing the conditioned strength by the unconditioned strength.
- Visual Strip Rating: The cores tested for tensile strength were visually evaluated to determine if stripping (moisture damage) had occurred in the HMA and the extent of the stripping that had occurred. The Visual Strip Rating was done according to the November 2003 IDOT procedure, "Stripping of Bituminous Mixtures Visual Identification and Classification."

- Penetration: The penetration test was performed on the asphalt binder from the tensile strength cores from each of the four groups. The asphalt binder was recovered after solvent extraction of the core material according to AASHTO T-49.
- Viscosity: The absolute viscosity was determined according to AASHTO T-202.
- PG Grade: The approximate PG Grade of the asphalt binder was determined using the Dynamic Shear Rheometer from the Grade Determination mode. This grade determination is an approximation because the mix has been in-place for several years and the asphalt has aged for that time.
- Infrared (IR) Analysis: The Infrared Spectrometer was used to analyze the chemical composition "fingerprint" of the recovered asphalt binder of the cores from the four areas to determine if the epoxy had contaminated the HMA. Also, samples of the epoxy taken from the runway were compared in the IR Spectrometer with new epoxy samples (both white and yellow).
- Freeze/Thaw Testing: Two of the cores from each of the four groups were subjected to multiple freeze/thaw cycles (starting 06/13/05) to evaluate the ability of the HMA to withstand the effect of seasonal freezing and thawing that occurs in Illinois.

RESULTS

The average test results for air voids, tensile strength, TSR, and visual strip rating is shown in Table 1.

		Runway # 31			Runway #4
		GN	BE	BN	4NE
	Gmm	2.455			2.460
Average	**Thickness (in)**	1.54	1.66	1.93	1.56
Average	**Gmb**	2.352	2.376	2.375	2.382
Average	**Voids**	4.2	3.3	3.3	3.2
Average	**Saturation (%)**	75.9	76.5	72.9	66.0
Average	**Tensile Strength (psi) (unconditioned)**	148.2	122.5	112.3	100.6
Average	**Tensile Strength (psi) (conditioned)**	134.2	104.9	112.6	96.1
Average	**Strip Rating (Coarse)**	1.0	1.0	1.0	1.5
Average	**Strip Rating (Fine)**	1.0	1.0	1.0	1.0
	TSR	0.906	0.856	1.003	0.956

Table 1

The individual results are shown in Table 2 and Table 3.

GN: Good - No Epoxy

	Thickness (in)	Voids (%)	Saturation (%)	Tensile Strength (psi)	Visual Strip Rating Coarse	Visual Strip Rating Fine
Unconditioned	1 3/8	2.7		147.6	1	1
	1 11/16	5.6		139.1	1	1
	1 11/16	4.2		158.0	1	1
Average	*1.583*	*4.2*		*148.2*	*1.0*	*1.0*
Maximum	*1.688*	*5.6*		*158.0*	*1.0*	*1.0*
Minimum	*1.375*	*2.7*		*139.1*	*1.0*	*1.0*
Range	*0.313*	*2.9*		*18.9*	*0.0*	*0.0*
Standard Deviation	*0.180*	*1.5*		*9.5*	*0.0*	*0.0*
Conditioned	1 7/16	2.4	69.6	135.6	1	1
	1 11/16	7.3	79.4	110.8	1	1
	1 3/8	3.0	78.8	156.3	1	1
Average	*1.500*	*4.2*	*75.9*	*134.2*	*1.0*	*1.0*
Maximum	*1.688*	*7.3*	*79.4*	*156.3*	*1.0*	*1.0*
Minimum	*1.375*	*2.4*	*69.6*	*110.8*	*1.0*	*1.0*
Range	*0.313*	*4.9*	*9.8*	*45.5*	*0.0*	*0.0*
Standard Deviation	*0.165*	*2.7*	*5.5*	*22.8*	*0.0*	*0.0*

BE: Bad - With Epoxy

	Thickness (in)	Voids (%)	Saturation (%)	Tensile Strength (psi)	Visual Strip Rating Coarse	Visual Strip Rating Fine
Unconditioned	1 5/8	2.9		115.1	1	1
	1 3/4	3.4		125.1	1	1
	1 9/16	3.5		127.3	1	1
Average	*1.646*	*3.3*		*122.5*	*1.0*	*1.0*
Maximum	*1.750*	*3.5*		*127.3*	*1.0*	*1.0*
Minimum	*1.563*	*2.9*		*115.1*	*1.0*	*1.0*
Range	*0.188*	*0.6*		*12.2*	*0.0*	*0.0*
Standard Deviation	*0.095*	*0.3*		*6.5*	*0.0*	*0.0*
Conditioned	1 5/8	2.7	77.4	90.6	1	1
	1 11/16	2.7	71.7	103.7	1	1
	1 11/16	4.4	80.3	120.3	1	1
Average	*1.667*	*3.3*	*76.5*	*104.9*	*1.0*	*1.0*
Maximum	*1.688*	*4.4*	*80.3*	*120.3*	*1.0*	*1.0*
Minimum	*1.625*	*2.7*	*71.7*	*90.6*	*1.0*	*1.0*
Range	*0.063*	*1.7*	*8.6*	*29.7*	*0.0*	*0.0*
Standard Deviation	*0.036*	*1.0*	*4.4*	*14.9*	*0.0*	*0.0*

Table 2

BN: Bad - No Epoxy

	Thickness (in)	Voids (%)	Saturation (%)	Tensile Strength (psi)	Visual Strip Rating Coarse	Visual Strip Rating Fine
Unconditioned	1 7/8	3.2		106.1	1	1
	2	2.8		103.5	1	1
	1 7/8	3.8		127.3	1	1
Average	*1.917*	*3.3*		*112.3*	*1.0*	*1.0*
Maximum	*2.000*	*3.8*		*127.3*	*1.0*	*1.0*
Minimum	*1.875*	*2.8*		*103.5*	*1.0*	*1.0*
Range	*0.125*	*1.0*		*23.8*	*0.0*	*0.0*
Standard Deviation	*0.072*	*0.5*		*13.1*	*0.0*	*0.0*
Conditioned	2	2.6	61.1	95.5	1	1
	1 15/16	4.0	77.8	112.9	1	1
	1 7/8	3.1	79.8	129.4	1	1
Average	*1.938*	*3.2*	*72.9*	*112.6*	*1.0*	*1.0*
Maximum	*2.000*	*4.0*	*79.8*	*129.4*	*1.0*	*1.0*
Minimum	*1.875*	*2.6*	*61.1*	*95.5*	*1.0*	*1.0*
Range	*0.125*	*1.4*	*18.7*	*33.9*	*0.0*	*0.0*
Standard Deviation	*0.063*	*0.7*	*10.3*	*17.0*	*0.0*	*0.0*

4NE: Runway #4 - No Epoxy

	Thickness (in)	Voids (%)	Saturation (%)	Tensile Strength (psi)	Visual Strip Rating Coarse	Visual Strip Rating Fine
Unconditioned	1 5/8	2.9		122.4	1	1
	1 1/2	3.0		90.2	2	1
	1 9/16	3.6		89.1	2	1
Average	*1.563*	*3.2*		*100.6*	*1.7*	*1.0*
Maximum	*1.625*	*3.6*		*122.4*	*2.0*	*1.0*
Minimum	*1.500*	*2.9*		*89.1*	*1.0*	*1.0*
Range	*0.125*	*0.7*		*33.3*	*1.0*	*0.0*
Standard Deviation	*0.063*	*0.4*		*18.9*	*0.6*	*0.0*
Conditioned	1 5/8	3.0	69.3	115.1	1	1
	1 9/16	2.1	65.4	107.0	1	1
	1 1/2	4.3	63.2	66.3	2	1
Average	*1.563*	*3.1*	*66.0*	*96.1*	*1.3*	*1.0*
Maximum	*1.625*	*4.3*	*69.3*	*115.1*	*2.0*	*1.0*
Minimum	*1.500*	*2.1*	*63.2*	*66.3*	*1.0*	*1.0*
Range	*0.125*	*2.2*	*6.1*	*48.8*	*1.0*	*0.0*
Standard Deviation	*0.063*	*1.1*	*3.1*	*26.2*	*0.6*	*0.0*

Table 3

The results from the Asphalt Chemistry Lab are shown in Table 4.

PG 64-22 ***?***	***Good no Epoxy*** ***GN***	***Bad with Epoxy*** ***BE***	***Runway #4 no Epoxy*** ***4NE***	***Bad no Epoxy*** ***BN***
BC#	654	657	656	655
Pen (dmm)	40	48	52	51
Viscosity (Pa·s)	601.7	424.6	478.9	395.3
IR analysis	normal	normal	normal	normal
Aprox. PG Final Grade	69	65	65	65

Table 4

DISCUSSION

- Air Voids: The air voids of all the cores from the four groups ranged from 2.1 to 7.3 percent with an average of 3.5 percent. All but 2 of the cores were between 2.1 and 4.4 percent. The 2 cores were both from the GN group. In each of the four groups, the range of voids of the three cores in each group was greater for the conditioned cores compared to the unconditioned cores.
- Tensile Strength: The tensile strengths of the twenty four cores ranged from 66.3 psi to 158 psi. The average strength was 116.4 psi. A strength value of greater than 100 psi for field cores is considered excellent. 80 to 100 psi is considered good, and 50 to 80 psi is considered fair. The cores from runway #31 that never had epoxy applied had the greatest average strength and the cores from runway #4 had the lowest average strength. The average strength of the cores from all four groups was good or better.
- TSR: The TSR values from the four groups ranged from 0.856 to 1.003. These values were all significantly greater than the minimum criterion of 0.75 for 4-inch diameter specimens. A value of greater than 1.0 shows that the conditioning did not degrade the specimens and in this case, the conditioned cores had an average strength slightly greater than the average unconditioned strength.
- Visual Strip Rating: Very little visual stripping, both in the coarse and fine aggregate, was seen in these cores. Some slight stripping was noticed on the coarse aggregate of three of the cores from runway #4. This is likely because the material on runway #4 has been in-place longer than the material on runway #31. The average coarse rating of all the cores was 1.1 and the average fine rating was 1.0. A rating of “1” indicates little or no stripping, a rating of “2” indicated moderate stripping, and a rating of “3” indicated severe stripping.
- Penetration: The penetration values of 40, 48, 52, and 51 are all representative of the same grade of asphalt, especially considering that this material has been in-place for several years. When asphalt has been in the pavement exposed to the elements and allowed to oxidize for several years, the lab test result values vary and can only be used to approximate the values of the original asphalt binder.
- Viscosity: The absolute viscosity of the asphalt binder ranged from 395 to 602 Pa-s. These values do not suggest that the asphalt grade was different for the different groups. This is especially true considering that the material has been in-place for several years.

- Approximate PG Final Grade: Based on the test values, the approximate high temperature Performance Grade of the asphalt binder is 65 to 69. The original asphalt grade for both runway #31 and runway #4 was probably PG 64-22.

The tests results on the recovered asphalt binder from the cores from runway #31 that never had epoxy applied show that it was slightly stiffer than the other cores. The lower penetration value and the higher viscosity value results in a slightly higher PG grade value as compared with the other 4 groups. When evaluating recovered asphalt binder from pavement cores, these differences are of little significance.

- Infrared (IR) Analysis: A detailed report (APPENDIX A), written by Violet Goodman from the BMPR Chemistry Lab, of the IR analysis of the HMA and the epoxy illustrates her findings. The cores from all four groups were chemically the same, indicating that no contaminants from the epoxy were present in the HMA. Also, her testing showed that the epoxy samples from the pavement, both white and yellow, were chemically the same as the new, lab-mixed samples from the same manufacturer.
- Freeze/Thaw Testing: The eight cores (two per area) that were tested in the freeze/thaw in the Concrete Lab. All were subjected to 381 freeze/thaw cycles, as of 08/02/05, with little or no deterioration.

After investigating literature from manufacturers of epoxy and of another agency that have extensive experience with epoxy striping paint applied on HMA, it is often the case that failure can be attributed to the application technique of the epoxy paint. Proper preparation of the existing surface, proper mixing of the epoxy components, proper calibration and cleaning of the application equipment, proper application techniques, thickness tolerances, and environmental variables must all be monitored and controlled.

SUMMARY

All the testing that was done indicates that the HMA composition and performance is typical of material that has been in-place for several years. None of the testing suggests that the HMA has deteriorated as a result of the epoxy striping or that it has performed outside of a normal range as a result of the epoxy striping.

APPENDIX A

INFRARED SPECTROMETER ANALYSIS

BACKGROUND AND OBJECTIVE

White and yellow samples of epoxy paint, and the nearby HMA core samples, were submitted to the Chemistry Instrument Laboratory by Tom Zehr for FTIR analysis:

1) core sample GN (good, no epoxy ever) – Control sample
2) core sample BN5 (bad, no more epoxy)
3) core sample BE3 (bad,epoxy still present)
4) pieces of white epoxy paint with HMA still stuck to them
5) pieces of yellow epoxy paint with HMA still stuck to them

Core samples and epoxy paint chips were analyzed by FTIR spectrometer to check if there is anything unusual about its molecular composition or properties that may explain why the paint is curling up or stripping off approximately 5 months after application.

LABORATORY PROCEDURE

I. HMA CORE ANALYSIS

A. USING TRICHLOROETHYLENE (TCE) AS SOLVENT

For each core, a six-gram sample was taken from the top layer in close proximity to the applied epoxy paint. Each 6-gram sample was dissolved in 10 ml of TCE Solution was mixed well and centrifuged at high speed for 10 minutes to completely separate out the aggregates and other fines. Two to three drops of the supernatant liquid were placed on a KBr plate, dried in the oven at 75^{o}C for 10 minutes, and analyzed using FTIR (Fourier Transform Infra-Red) spectrometer.

HMA stuck to the epoxy paint was plucked out and analyzed in the same manner.

B. USING METHYLENE CHLORIDE (MC) AS SOLVENT
(This is the only solvent currently available in the laboratory that can partially disintegrate the epoxy paint).

Above procedure was repeated using a much stronger extracting solvent, methylene chloride.

II. EPOXY PAINT ANALYSIS

Approximately 4 small pieces of each type of epoxy paint (white and yellow), with the least amount of asphalt in them, were dissolved in MC, shaken and allowed to stand for ~ 1 hour to complete the extraction. Two to three drops of the clear supernatant liquid were placed on a KBr plate, air dried for 10 minutes, and analyzed using FTIR (Fourier Transform Infra-Red) spectrometer.

III. LABORATORY EPOXY MIX AS REFERENCE MATERIAL

Reference materials of white and yellow epoxy paint were prepared by mixing part A (the paint) and part B (the hardener) in 2:1 ratio respectively as recommended by the manufacturer. Glass beads were also added. The same brand of paint (POLY-CARB, INC) as was used in Mt. Carmel Airport Runway 31, was used. The same extraction procedure II above was used for these samples at 2-hour and 3-day curing times.

RESULTS

See attached IR (infra-red) spectra. The resultant spectra or graphical representation is unique for each substance and is based on specific functional groups in its molecular structure. It is considered as the substance's fingerprint.

The spectra for all samples are shown on top of each other on the same coordinates for ease of comparison.

See Figure 1 for HMA core analysis using TCE as extraction solvent:

The spectra of all HMA samples are all identical to the control sample and do not show any unusual peaks. They also did not show any identifying peak for the SBS polymer that is used in polymer modified asphalt cement. This spectrum is typical of PG graded asphalt cement that is dissolved in TCE.

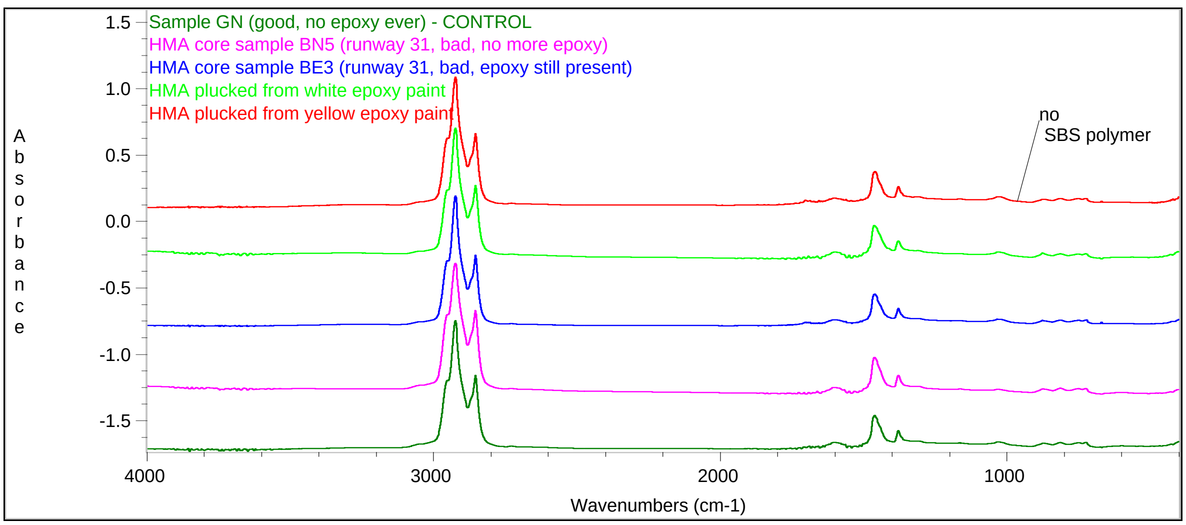

Figure 1 – HMA extracts using trichloroethylene

See Figure 2 for HMA core analysis using MC as extraction solvent:

The spectra of all HMA samples are all identical to the control sample and do not show any unusual peaks. This spectrum is typical of asphalt cement that is dissolved in MC.

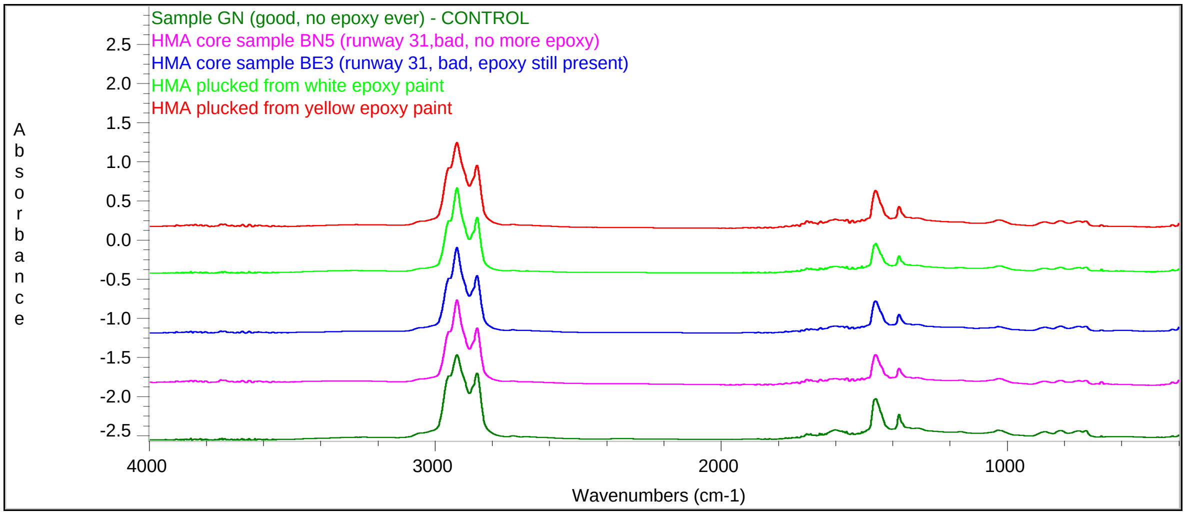

Figure 2 – HMA extracts using methylene chloride

See Figure 3 for white epoxy paint analysis using MC as extraction solvent:

Both field (runway 31) and laboratory samples of the white epoxy paint showed the major peaks found in both component parts A and B of the epoxy paint system.

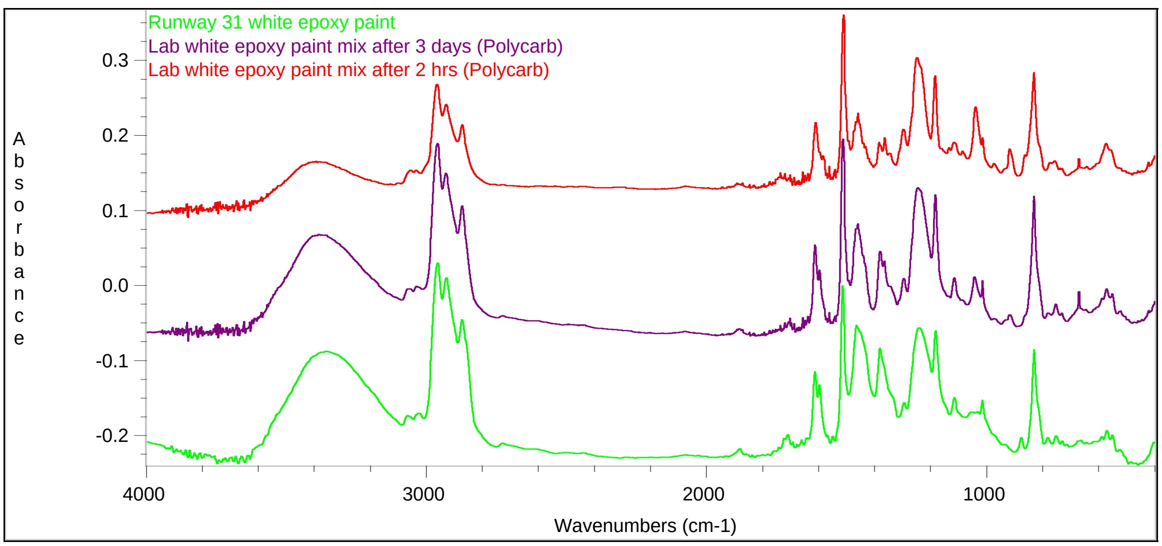

Figure 3 – White epoxy paint extracts using methylene chloride

See Figure 4 for yellow epoxy paint analysis using MC as extraction solvent:

Both field and laboratory samples (reference materials) of the yellow epoxy paint showed the major peaks found in both component parts A and B of the epoxy paint system.

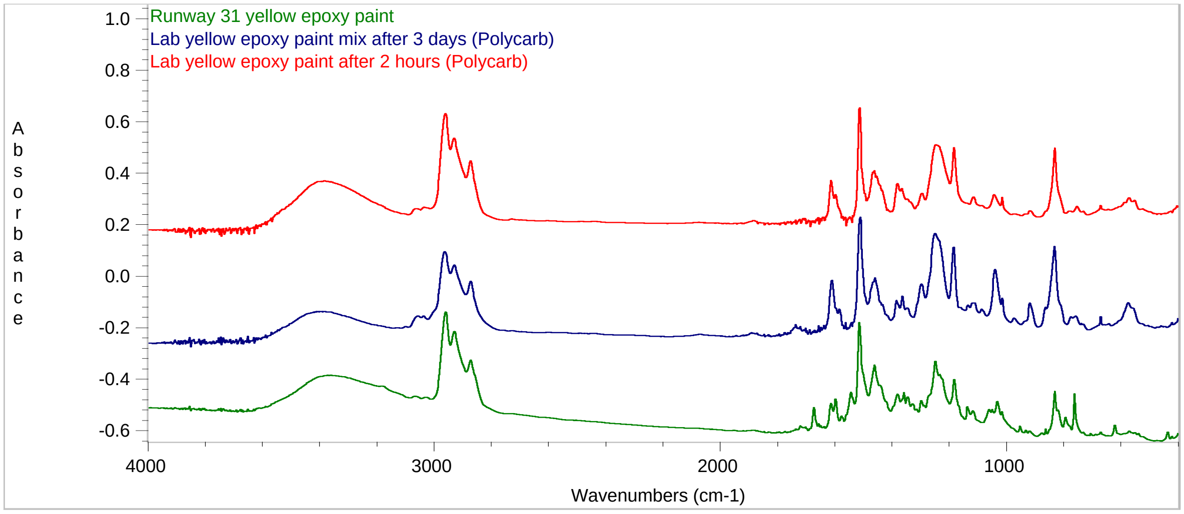

Figure 4 – Yellow epoxy paint extracts using methylenechloride

NOTE: The spectra of both parts A and B of the epoxy paint from POLY-CARB, INC. were identical to those of their competition, EPOPLEX

CONCLUSION

The HMA analysis showed normal spectra for PG grade asphalt cement.

The analysis of the epoxy paint samples from Runway 31 showed the same major peaks in the reference materials which in turn were the same major peaks in the components.

Some minor peaks, either present or absent, from the Runway 31 spectra maybe due to some other chemicals that the paint may have been exposed to out in the runway. These chemicals may or may not have reacted with parts of the molecular structure of the cured paint; or with the excess, non-reactive components of the paint. It is not possible at this point to determine what those chemicals are.

This shows that the correct epoxy paint was used, and that it was used in the correct ratio. As per manufacturer, if the component ratio is not correct, 1) the paint will not cure at all and will be tacky 2) the colors will not look right and there will be brown spots on the paint.

ADDITIONAL COMMENTS

Notes from conversation with Michael Mourod, Great Lakes Sales Manager for EPOPLEX:

- He does not recommend applying epoxy paint over fresh HMA. It should be allowed to age for 2-3 weeks before applying the paint, even though the application guidelines state that the paint can be applied to new asphalt surfaces as soon as the asphalt has cooled and can support the weight of the application equipment. The asphalt must be free of excess asphalt emulsion and oils to ensure proper adhesion of the markings.

- He noticed some of the epoxy paint submitted to the Chemistry Lab was too thick. He recommended application thickness is 20 – 25 mils.